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LA COLLECTION DE BOIS DU CIRAD / LE POINT SUR...

Description of the Cirad wood collection in Montpellier, France, representing eight thousand identified species

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Image of the wood collection (Xylotheque): open drawer with 3 rows of specimens.

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RÉSUMÉ

Description de la xylothèque du Cirad à Montpellier, France, regroupant huit mille espèces identifiées

La xylothèque du Cirad est composée d'échantillons provenant de 34 395 arbres issus de 123 pays, appartenant à 235 familles, 2 160 genres et 8 385 espèces (dont 60 % sont représentées par plus d'un spécimen par arbre). Les espèces d'Afrique, d'Asie et d'Amérique représentent 85 % de la collection. Une description botanique des familles, genres et espèces les plus représentés a été faite dans les dix régions géographiques pour lesquelles il y a suffisamment d'échantillons (plus de 1 000). Ces régions comprennent neuf régions tropicales ou subtropicales et une grande entité appelée « Climat Froid du Nord » (NCC), qui couvre tous les pays de l'hémisphère nord ayant une saison froide marquée (climats boréal, alpin tempéré et méditerranéen). Les neuf régions tropicales et subtropicales ont plus ou moins les mêmes familles dominantes, mais différents genres dominants alors que les familles dominantes dans l'entité NCC diffèrent largement. La collection est décrite dans une base de données spécifique : échantillons de bois, sections et photographies avec leurs noms et provenance. La densité a été mesurée pour les deux tiers des spécimens (6 750 espèces). Dans l'ensemble, les valeurs de la densité ont une distribution presque normale dans une plage de 0,04 à 1,36, avec une médiane de 0,72 et un coefficient de variation (CV) de 28 %. La différence entre régions, quant à la distribution de la densité, est assez faible (valeurs moyennes variant de 0,66 à 0,76) avec un CV systématiquement élevé (26 % à 32 %). En examinant les familles, genres et espèces les mieux représentés, le CV moyen pour les familles (26 %) est similaire à celui des régions et beaucoup plus bas pour les genres (18 %) et espèces (13 %). L'éventail des densités augmente de la famille au genre et à l'espèce (0,53 à 0,86, 0,46 à 0,95, 0,23 à 1,07 respectivement). Dans l'article, les différents usages actuels et potentiels de la xylothèque sont discutés.

Mots-clés : xylothèque, espèces, genres, familles, provenance, densité du bois, collection de bois, base de données de bois, espèces tropicales, France.

ABSTRACT

Description of the Cirad wood collection in Montpellier, France, representing eight thousand identified species

The CIRAD wood collection, which was first awarded funding 80 years ago, now consists of specimens from 34,395 trees, 235 families, 2,160 genera and 8,385 species (of which 60% are represented by more than one specimen per tree) from 123 countries. Tropical species from Africa, Asia and South America make up 85% of the collection. Botanical descriptions have been made of the dominant families, genera and species in the ten geographical regions for which there are large enough collections (1,000+ specimens). These regions include nine tropical or subtropical regions and a large entity called "Northern Cold Climate" (NCC), which covers all northern hemisphere countries with a cold season (boreal, alpine temperate and Mediterranean climate). The nine tropical and subtropical regions have more or less the same dominant families but different dominant genera, while dominant families in the NCC entity differ widely. The collection is described in a specific data base: wood specimens, sections and photographs with their name and provenance. Specific Gravity (SG) has been measured in two thirds of all the specimens (6,750 species). Overall, SG values have a near normal distribution ranging from 0.04 to 1.36, with a median value of 0.72 and a 28% coefficient of variation (CV). The difference between regions in specific gravity distribution is quite small (mean values 0.66 to 0.76) with a consistently high CV (26% to 32%). Looking at the best represented families, genera and species, the mean CV for families (26%) is similar across regions and much lower for genera (18%) and species (13%). The SG range increases from family to genus to species (0.53 to 0.86, 0.46 to 0.95, 0.23 to 1.07 respectively). The different current and potential uses of the wood collection are discussed.

Keywords: xylotheque, species, genera, families, provenance, wood density, wood collection, wood database, tropical species, France.

RESUMEN

Descripción de la colección de madera Cirad en Montpellier, Francia, que representa ocho mil especies identificadas

La colección de madera del Cirad consiste en muestras de 34 395 árboles, 235 familias, 2 160 géneros y 8 385 especies (60 % de los cuales están representados por más de una muestra por árbol) de 123 países. Las especies tropicales de África, Asia y Sudamérica constituyen el 85 % de la colección. Se han realizado descripciones botánicas de las familias dominantes, géneros y especies en diez regiones geográficas para las cuales hay colecciones suficientemente grandes (más de 1 000 muestras). Estas regiones incluyen nueve regiones tropicales o subtropicales y una gran entidad llamada «Clima frío del norte» (NCC), que abarca todos los países del hemisferio norte con una estación fría (climas boreal, alpino templado y mediterráneo). Las nueve regiones tropicales y subtropicales tienen más o menos las mismas familias dominantes, pero diferentes géneros dominantes; mientras que las familias dominantes en la entidad NCC difieren ampliamente. La colección se describe en una base de datos específica: muestras de madera, secciones y fotografías con su nombre y proveniencia. La gravedad específica (SG) se ha medido en los dos tercios de las muestras (6 750 especies). Globalmente, los valores SG tienen una distribución casi normal en el rango de 0,04 a 1,36, con una mediana de 0,72 y un coeficiente de variación del 28 % (CV). La diferencia entre las regiones en una distribución de gravedad específica es bastante pequeña (valores medios de 0,66 a 0,76) con un CV consistentemente elevado (26 % a 32 %). Mirando las familias mejor representadas, géneros y especies, el CV medio para las familias (26 %) es similar en todas las regiones y mucho más bajo para los géneros (18 %) y especies (13 %). El rango SG aumenta de familia a género y a especie (0,53 a 0,86, 0,46 a 0,95, 0,23 a 1,07 respectivamente). En el artículo se analizan los diferentes usos actuales y potenciales de la colección de madera.

Palabras clave: xiloteca, especies, géneros, familias, proveniencia, densidad de la madera, colección de madera, base de datos de madera, especies tropicales, Francia.

History and scope

The CIRAD wood collection (Xylotheque) was established rather recently (in 1937) when compared to other wood collections (Stern 1988; Cornish *et al.*, 2014; Lens, 2016), by Didier Normand, head of the wood anatomy laboratory at the former STBC (*Section Technique des Bois Coloniaux* or Colonial Wood Technical Section) at Nogent-sur-Marne, near Paris, France (Norman *et al.*, 2017). STBC was replaced by CTFT (*Centre Technique Forestier Tropical* or Tropical Forest Research Institute) in 1949, and then became part of CIRAD (*Centre de Coopération Internationale en Recherche Agronomique pour le Développement* or French Agricultural Research Centre for International Development) in 1985. Alain Mariaux and Pierre Détienne were the subsequent curators of the Xylotheque, which was transferred to Montpellier in 1994.

Systematics were not the primary objective for Cirad institution, although D. Normand and P. Détienne could be qualified as systematic wood anatomists. There was a close cooperation between them and the National Museum in Paris (Le Bras *et al.*, 2017) where most of the herbarium vouchers associated with wood specimens are stored. For the trees coming from French Guyana, herbarium vouchers are stored in the Cayenne herbarium (IRD), and there is a Xylotheque annex in the CIRAD wood laboratory in Kourou (French Guiana).

There was a strong collecting effort between 1950 and 1990 related to a general striving for knowledge and use of woods from the former French colonies in order:

- to help the huge building effort and the high demand of timber in France after the first and second World Wars;
- to cope with the large population growth after the second World War;
- to help in the development of wood industries in new independent countries at the beginning of the sixties.

At the outset, Didier Normand and other scientists took a pragmatic approach based on a reference number (CTFT id) given to trees (or logs from this tree) that were delivered to the CTFT facilities (sawmill and carpentry workshop). The numbers are given in ascending order from the beginning (1 to 34,395). This CTFT id. is the common reference for all wood specimens derived from the same tree, for the different wood property measurements including a group of "anatomical" specimens (usually 10 per tree). The first specimens (CTFT id. from one to some hundreds) were specimens from older collections when species identification was certified. The reference number was decided by the wood anatomy laboratory in relation to botanical identification, usually with Paris and Cayenne herbariums, and associated vouchers are positioned in these herbariums[1]. For each of these CTFT ids there is a reference wood specimen (photos 1) in the basic collection (photos 2). Other anatomical specimens from the same tree (duplicates) are stored in a backup wood collection usable for exchanges and further scientific works.

[1] It should be noted that not all trees (CTFT id) have an identified associated voucher. This is the case for i) some samples coming from exchanges, ii) trees in great number from a same species, iii) other cases when identification was guaranteed for well known species, often from temperate countries. The information is given in the data base.

Photos 1.
Sample pictures: CTFT id. 1, 20642 and 34395.

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Photos 2.
Images of the wood collection (Xylotheque). Top left: drawer chest with the reference collection. Top right: open drawer with 3 rows of specimens. Bottom left: drawers with complementary specimens. Bottom right: drawer with slide collection.

Description of the collection

There are no specimens from shrubs or lianas in the collection, with very few exceptions. The very large majority are standard specimens (13 cm x 6 cm x 1 cm) with a label bearing the CTFT id., country of origin, botanical name and, sometimes, information on the origin (collector), the local name of the tree, and specific gravity of the specimen (photos 1 and 2).

In all, there are 34,395 specimens (CTFT id.) in the collection (table I) with 235 identified families, 2,160 identified genera and 8,385 identified species. Only 71 specimens (0.2%) are unidentified at family level and 281 specimens (0.8%) are identified only at family level (47 families). The number of specimens (trees) unidentified at the species level is much higher: 4,477 specimens (13%) from 779 genera. For the majority of trees not fully identified there is a majority of associated vouchers, more or less the same proportion as for fully identified ones. This happens mostly in families (Lauraceae for example) or genera (*Ocotea*, *Ravensara* for example) whose determination is difficult and many vouchers in herbarium are still waiting to be identified. The consultation from Paris and Cayenne herbariums makes it possible to progress on the reference of partially identified specimens.

For around 60% of the species there is at least one duplicate specimen (from 1 to 9 specimens per CTFT id.) stored in the supplementary collection. They can be used for further analysis in different fields (including destructive tests if necessary) or for exchanges with other collections. There is also a similar number of off-cuts, portions of standard specimens after sectioning or sub-sampling operations for different uses (photos 2).

For most of the species, there are sections (7,007 microscope slides) for transmitted light microscopy in the 3 standard planes (TS, RLS and TLS). Around 3,000 micro photos at x25 magnification taken from these sections are stored in the same place (photos 2).

For rapid identification with the aid of a lens or stereo-microscope, small oriented cubes (1 x 1 x 1 cm) for around 70% of the collection are stored by CTFT id.

Filing cards with extensive information are available for each reference specimen.

Database

All the informative data and metadata on the collection are recorded in digital files since 1980; the process was initiated by Mariaux and Narboni (1996). The data files are regularly updated with: new specimens, change of botanical name due to nomenclature changes or revised identification of the herbarium voucher or the wood specimen. Reference web sites as Tropicos[2] or INPI[3] (International Plant Names Index) are mostly used.

[2] Topicos database: http://www.tropicos.org)

[3] INPI (International Plant Names Index) database: https://www.ipni.org)

Table I.
General description of the collection.

Collection	Global	Gymno	Angio	Identified	SG ident.	H. voucher	Duplicate
Sample	34,395	931	33,364	28,566	19,289	18,620	18,221
Family	236	5	231	235	205	207	193
Genus	2206	42	2164	2,160	1,809	1,822	1,576
Species	9,213	250	8,963	8,355	6,570	6,777	5,308

Global: all CTFT references; Gymno: gymnosperm references; Angio: angiosperm references; Identified: totally identified sample at species level; SG ident.: identified sample with specific gravity (SG) measurement; H. voucher: sample associated to herbarium voucher; Duplicate: CTFT reference with at least one replicate; Sample: number of CTFT references; Family: number of documented family; Genus: number of documented genus; Species: number of documented species.

There are 6 tables within the database:

- a collection table, which is merely a transcription of registering notebooks with 10 fields: CTFT id., country of provenance, local name, codified botanical identification (3 letters and 9 figures), herbarium voucher occurrence, duplicate specimen number, technological test, collector or collection origin (name + code), and other information;
- a family table with 2 fields: codified family (3 letters) and full name of the family;
- a species table with 2 fields: codified botanical name composed of 9 characters (3 letters for the family, 3 figures for the genus and 3 figures for the species) and full scientific denomination of the species;
- a provenance table (country) with 3 fields: codified country, name of the country, name of continent or subcontinent (list of 9 different names);
- a density table (specific gravity) with 2 fields: CTFT id. and specific gravity of the item measured more or less under standard climatic conditions (around 20 °C and 65% RH);
- a complementary table with 9 fields: CTFT id., storing address of associated reference slide, storing address of associated 2nd slide, storing address of associated 3rd slide, technological test number, presence of x25 magnification photos in TR plane, occurrence of both x25 magnification photos in the 3 standard planes and x55 magnification photos in TLS plane, presence of supplementary section associated with the technological test, presence of left over materials.

For the data associated to this paper (2 tabular files in CSV format in open access) most of important information including herbarium vouchers are kept, but not some data as the place where you can find photographs or sections.

Geographical distribution of the specimens

All continents except the Antarctic are represented. Africa has the largest number of specimens (45.8%) followed by South America (30.5%), Asia (13.4%), Oceania (4.4%), North America (4.0%) and Europe (1.9%). There are specimens from 123 countries. The Republic of France, including Metropolitan France (Europe) and French overseas departments and territories, such as French Guiana, Guadeloupe, Martinique, Reunion Island, New Caledonia and French Polynesia, accounts for the largest number of specimens (6,120 including 3,654 from French Guiana) with around 1,500 native species and 100 exotic species (plantations).

The top ten countries considering the total number of specimens are France (17.9%), Madagascar (9.9%), Cameroon (7.3%), Gabon (6.7%), Ivory Coast (5.4%), Republic of the Congo (5.3%), Brazil (5%), Vietnam (3%), Ecuador (2.8%) and Suriname (2.6%).

Overall, 88% of the specimens can be described as tropical wood from dry or rain forests in Africa, Asia, America and Oceania. Temperate or Mediterranean species account for the remaining 12%.

In order to go further in the description of the collection, it was decided to separate the tropical and sub-tropical regions into 9 geographical entities accounting for a great number of specimens: Tropical East Africa (AfEst, 873 specimens), Tropical West Africa (AfTH, 9,668 specimens), Tropical Asia (AsTH, 2,842 specimens), Tropical America (AmTH, 8,300 specimens), Tropical Isles from the Indian Ocean (Mada, 3,851 specimens), Tropical Isles from the Caribbean sea (Cara, 1,424 specimens), Sub-tropical North Africa (AfSA, 922 specimens), Indian sub-continent (India, 780 specimens), and Oceania (Ocea, 1,526 specimens). Boreal, temperate and Mediterranean forests from the northern hemisphere have been grouped in a large entity called “Northern Cold Climate” (NCC, 2,788 specimens).

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Table II.
Top ten families and total number of families for the different regions. In blue, global top ten families.

Family Order	Total	NCC	AfEst	AfSa	Af TH	AmTH	AsTH	Cara	India	Mada	Ocea
1	CES	PIN	CES	MIM	CES	CES	DIP	MEL	MIM	LAU	MYT
2	MIM	FAG	MIM	CES	MEL	FAB	CES	LAU	FAB	FAB	MIM
3	FAB	ROS	COB	FAB	MAL	LAU	MEL	FAB	COB	SAP	MEL
4	LAU	BET	FAB	COB	SAP	MIM	LAU	RUB	MEL	MAL	LAU
5	MEL	CUP	RUB	MEL	MIM	SAP	MAL	MYT	CES	MEL	SPI
6	SAP	SPI	EUP	MAL	RUB	LEC	ANA	CES	MOR	RUB	RUB
7	MAL	LAU	MEL	MYT	ANO	MOR	FAB	MIM	RUB	SPI	MAL
8	RUB	SAL	PHL	PHL	BUR	CHR	FAG	SAP	PIN	MYT	SAP
9	MYT	FAB	MAL	ANA	EUP	MAL	SAP	MAL	DIP	MIM	CAH
10	MOR	OLE	PRO	MOR	COB	VOC	MYT	BIG	MYT	CLU	PRO
Nb Families	235	136	85	57	104	131	110	90	80	109	93

ANA: Anarcadiaceae; BET: Betulaceae; BIG: Bignoniaceae; CAH: Calophyllaceae; CES: Caesalpinoideae; CHAR: Chrysobalanaceae; CLU: Clusiaceae; COB: Combretaceae; CUP: Cupressaceae; EUP: Euphorbiaceae; FAB: Fabiodeae; FAG: Fagaceae; LAU: Lauraceae; LEC: Lecythidaceae; LEC: Lecthidaceae; MAL: Malvaceae; MEL: Meliceae; MIM: Mimosoideae; MOR: Moraceae; MYT: Myrtaceae; OLE: Oleaceae; PHL: Phyllanthaceae; PIN: Pinaceae; PRO: Proteaceae; ROS: Rosaceae; RUB: Rubiaceae; SAL: Salicaceae; SAP: Sapotaceae; SPI: Sapindaceae; VOC: Vochysiaceae; AfEst: Tropical East Africa; AfTH:Tropical West Africa; AsTH: Tropical Asia Tropical; AmTH: Tropical America; Mada: Tropical Isles from the Indian Ocean; Cara: Tropical Isles from the Caribbean sea; AfSA: Sub-tropical North Africa; India: Indian sub-continent; Ocea: Oceania; NCC: Northern Cold Climate.

There is a clear over representation of former French overseas regions and former colonies in Africa, America and Oceania. The ten geographical entities that will be described are not representative of any ecological biome but just facilities for the collection description.

Botanical distribution of the specimens

The botanical classification used is the one presented by Stevens (2017) on the Missouri Botanical Garden website[4].

Gymnosperms account for only 1,036 specimens, 6 families, 53 genera and 286 species (between 2% and 3% of the total in each category).

There are only 56 families with more than 100 specimens (24% of the families) but they account for 90% of the total number of specimens. The Leguminosae family (Mimosoideae, Caesalpinioideae and Faboideae sub families) is grouping more than 4,000 specimens (20% of all the specimens). The Meliaceae, Lauraceae, Sapotaceae and Malvaceae also amount to more than 1,000 specimens.

Within the top ten families (or sub families) at global level (table II), there are only a few major tropical families which have some representatives in temperate or Mediterranean forests (Faboideae and Lauraceae, for example). Looking at the top ten families in each of the 10 geographical entities, NCC has a clearly different group with only 20% of families present in the global top ten, while all tropical and sub-tropical regions have between 60% and 90% of the most frequent families.

In the boreal, temperate, Mediterranean and sub-tropical forests of the northern hemisphere (NCC), Fagaceae and Pinaceae clearly dominate and it is the only region where gymnosperms are abundant. Between the 9 regions where tropical families dominate, there are some differences, and 4 regions do not have one of the top 3 for their own top family: South-East Asia where Dipterocarpaceae dominate, Madagascar, Carribean and Oceania where it is the Lauraceae, Meliaceae and Myrtaceae which dominate, respectively.

Looking at genera (table III), their total number is always large (› 300) except for the "smaller" regions (AfEst, AfSa and India). Within the top ten genera at global or regional level, the differences are much greater than for the families, and no genus is the top one in more than one region. Most of these top ten consist of genera comprising numerous important commercial timbers, often emblematic of their region, such as *Quercus*, *Pinus*, *Acacia*, *Eucalyptus*, *Swietenia* or *Khaya*, *Diospyros*, *Shorea*, *Entandophragma*, or *Dalbergia*.

The top 10 genera in the column "Total" have colors which are kept in the regional columns in order to see whether they are still present in the top 10 genera of this region.

[4] Missouri Botanical Garden website:
https://www.mobot.org/MOBOT/research/APweb/

Table III.
Top ten genera and total number of genera for the different regions. The top 10 genera in the column "Total" have colors which are kept in the regional columns in order to see whether they are still present in the top 10 genera of this region.

Order	Total	NCC	AfEst	AfSa	AfTH	AmTH	AsTH	Cara	India	Mada	Ocea
1	*Terminalia*	*Quercus*	*Combretum*	*Albizia*	*Entandrop.*	*Licania*	*Shorea*	*Swietenia*	*Terminalia*	*Dalbergia*	*Eucalyptus*
2	*Diospyros*	*Pinus*	*Acacia*	*Acacia*	*Terminalia*	*Pouteria*	*Dipterocar.*	*Zanthoxy.*	*Acacia*	*Ravensara*	*Acacia*
3	*Dalbergia*	*Acer*	*Brachystegia*	*Pterocarpus*	*Dacryodes*	*Ocotea*	*Hopea*	*Tabebuia*	*Syzygium*	*Cryptocarya*	*Calophyllum*
4	*Albizia*	*Picea*	*Pterocarpus*	*Daniellia*	*Diospyros*	*Inga*	*Syzygium*	*Cordia*	*Dalbergia*	*Ocotea*	*Syzygium*
5	*Ocotea*	*Abies*	*Entandrop.*	*Ficus*	*Xylopia*	*Eschweilera*	*Diospyros*	*Sloanea*	*Albizia*	*Syzygium*	*Elaeocarpus*
6	*Entandrop.*	*Prunus*	*Monotes*	*Combretum*	*Celtis*	*Swartzia*	*Parashorea*	*Byrsonima*	*Ficus*	*Symphonia*	*Cryptocarya*
7	*Quercus*	*Fraxinus*	*Albizia*	*Khaya*	*Gilbertiod.*	*Vochysia*	*Tarrietia*	*Dacryodes*	*Toona*	*Terminalia*	*Melaleuca*
8	*Syzygium*	*Betula*	*Terminalia*	*Afzelia*	*Brachystegia*	*Virola*	*Dalbergia*	*Cedrela*	*Bauhinia*	*Albizia*	*Santalum*
9	*Pinus*	*Ulmus*	*Commiphora*	*Detarium*	*Gambeya*	*Lecythis*	*Aglaia*	*Terminalia*	*Acer*	*Diospyros*	*Planchonella*
10	*Acacia*	*Populus*	*Ficus*	*Bombax*	*Prioria*	*Brosimum*	*Sindora*	*Hymenaea*	*Artocarpus*	*Weinmannia*	*Dysoxylum*

Acronyms for the different regions: AfEst: Tropical East Africa; AfTH:Tropical West Africa; AsTH: Tropical Asia Tropical; AmTH: Tropical America; Mada: Tropical Isles from the Indian Ocean; Cara: Tropical Isles from the Caribbean sea; AfSA: Sub-tropical North Africa; India: Indian sub-continent; Ocea: Oceania; NCC: Northern Cold Climate.

Table IV.
SG values for the different regions.

Region	Nb ref	SG min	SG max	SG mean	CV SG
AfEst	368	0.06	1.27	0.72	29%
AfSa	781	0.10	1.27	0.71	28%
AfTH	6,996	0.14	1.25	0.70	27%
AmTH	4,261	0.10	1.34	0.75	29%
AsTH	1,924	0.04	1.32	0.69	28%
India	422	0.26	1.20	0.67	27%
Cara	848	0.12	1.36	0.71	32%
Mada	3,076	0.11	1.30	0.76	26%
Ocea	946	0.16	1.28	0.71	29%
NCC	1,350	0.24	1.32	0.66	26%

Nb ref: number of specimens; SG mean: mean specific gravity (SG) value for the group; SG max: maximum specific gravity (SG) value for the group; SG min: minimum specific gravity (SG) value for the group; CV SG: coefficient of variation for SG values within the group; AfEst: Tropical East Africa; AfTH: Tropical West Africa; AsTH: Tropical Asia Tropical; AmTH: America America; Mada: Tropical Isles from the Indian Ocean; Cara: Tropical Isles from the Caribbean sea; AfSA: Sub-tropical North Africa; India: Indian sub-continent; Ocea: Oceania; NCC: Northern Cold Climate.

Table V.
SG values for families with at least 500 measured specimens.

Region	Nb ref	SG min	SG max	SG mean	CV SG
Euphorbiaceae	552	0.15	1.21	0.53	35%
Burseraceae	540	0.15	1.10	0.58	25%
Malvaceae	882	0.10	1.24	0.59	35%
Moraceae	591	0.20	1.32	0.61	31%
Meliaceae	1,028	0.30	1.21	0.64	21%
Lauraceae	902	0.28	1.25	0.66	23%
Annonaceae	523	0.21	1.10	0.66	29%
Mimosaceae	1,061	0.25	1.30	0.71	27%
Rubiaceae	723	0.29	1.13	0.73	20%
Caesalpiniaceae	2,291	0.28	1.36	0.78	24%
Fabaceae	913	0.06	1.30	0.81	26%
Sapotaceae	969	0.30	1.33	0.86	21%

Nb ref: number of specimens; SG mean: mean specific gravity (SG) value for the group; SG max: maximum specific gravity (SG) value for the group; SG min: minimum specific gravity (SG) value for the group; CV SG: coefficient of variation for SG values within the group.

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Table VI.
SG values for genera with at least 149 measured specimens.

Species	Nb ref	SG min	SG max	SG mean	CV SG
Ficus	151	0.20	0.80	0.46	22%
Ocotea	190	0.36	0.97	0.60	18%
Albizia	222	0.30	0.97	0.62	19%
Entandrophragma	241	0.40	0.81	0.62	13%
Dacryodes	177	0.44	0.99	0.63	15%
Xylopia	181	0.27	1.08	0.73	25%
Terminalia	189	0.35	1.15	0.74	23%
Syzigium	183	0.45	1.09	0.78	13%
Acacia	149	0.44	1.24	0.85	22%
Diospyros	208	0.48	1.32	0.86	16%
Dalbergia	198	0.44	1.27	0.93	16%
Pouteria	162	0.49	1.33	0.95	17%

Nb ref: number of specimens; SG mean: mean specific gravity (SG) value for the group; SG max: maximum specific gravity (SG) value for the group; SG min: minimum specific gravity (SG) value for the group; CV SG: coefficient of variation for SG values within the group.

Table VII.
SG values for species with at least 40 measured specimens.

Species	Nb ref	SG min	SG max	SG mean	CV SG
Musanga cecropioides	40	0.14	0.48	0.23	31%
Aucoumea klaineana	62	0.31	0.64	0.41	16%
Pycnanthus angolensis	86	0.31	0.90	0.48	18%
Coelocaryon preussii	43	0.36	0.64	0.48	15%
Swietenia macrophylla	51	0.40	0.78	0.53	15%
Scyphocephalium mannii	44	0.34	0.77	0.54	17%
Lovoa trichilioides	42	0.43	0.80	0.55	13%
Entandrophragma angolense	61	0.42	0.80	0.58	14%
Milicia excelsa	56	0.43	0.73	0.60	12%
Entandrophragma utile	42	0.40	0.74	0.60	13%
Entandrophragma cylindricum	73	0.48	0.80	0.65	9%
Tetraberlinia bifoliolata	46	0.47	0.86	0.67	14%
Piptadenia africana	55	0.48	0.89	0.68	13%
Cryptocarya thouvenotii	42	0.51	0.83	0.69	11%
Nauclea diderrichii	46	0.56	0.84	0.72	8%
Dicorynia guianensis	47	0.59	0.93	0.77	10%
Staudtia kamerunensis	43	0.73	1.01	0.85	9%
Lophira alata	42	0.97	1.19	1.07	6%

Nb ref: number of specimens; SG mean: mean specific gravity (SG) value for the group; SG max: maximum specific gravity (SG) value for the group; SG min: minimum specific gravity (SG) value for the group; CV SG: coefficient of variation for SG values within the group.

Distribution of specific gravity

Specific gravity (SG) is the ratio between wood density (in kg/m^3) and water density under the same conditions. As the specific gravity of cell wall matter is 1.5, all wood SG should be below 1.5, with a direct relation to wood porosity and fiber wall thickness: high porosity and thin fibre walls imply low SG. Wood is part of the global class of cellular materials (mostly honeycombs), for which SG is a key parameter for most physical and mechanical properties (Gibson 2005). It is usual to consider SG as the most important descriptor for wood and it is used both by technologists (Forest Products Laboratory, 2010), ecologists (Chave *et al.*, 2006; Beeckmann, 2016; Baker *et al.*, 2004; Nock *et al.*, 2009) tree physiologists (Bossu *et al.*, 2016; Wiemann and Williamson, 1998) or foresters (Bouriaud *et al.*, 2004, 2005) in order to i) guide end uses, ii) look at phylogenetic variations among regions, iii) examine ontogenetic variation in wood formation or iv) analyse forest management impacts.

In the current data files, SG has been measured on 2/3 of all the specimens[5]. Overall, SG values have a near normal distribution ranging from 0.04 to 1.36, with a median value 0.72 and a standard deviation of 0.20, very similar to results in Détienne and Chanson (1996) for a large selection in the collection.

Within the specimens identified at species level (table I) there are 205 families (87% of all identified specimens), 1,809 genera (84%) and 6,750 species (79%). The mean SG value can be calculated for each of the species or genus, but for many of them there are few or very few specimens and the mean value has only a poor indicative value, as SG is often highly variable at species or tree level. SG distribution has only been examined for some populations with a large number of specimens:

- Region level (table IV). For the 10 regions, the number of measured specimens is below 500 for only 2 regions: AfEst (368) and India (422) and over 1,000 for half of them. The coefficient of variation (CV) is always high (26% to 32%), near the CV for the total collection (28%) and the mean values are rather close between regions (0.66 to 0.76), near the general mean (0.72).
- Family level (table V). Looking at the 12 large families grouping at least 500 measured specimens, the CV values are still very high (21% to 35%). However, the differences in mean values are greater (0.53 to 0.86).
- Genus level (table VI). Twelve genera are represented by at least 150 measured specimens. The coefficient of variation for SG values is lower than the CV for regions or families and more variable (13% to 25%). The differences in mean values are large (0.46 to 0.95).
- Species level (table VII). Eighteen species are represented by at least 40 measured specimens. The coefficient of variation for the SG values is lower than the CV for genera and much more variable (6% to 31%). The differences in mean values are very large (0.23 to 1.07).

Genus, and mostly species, distribution should be the main factor for differences between regions. It should be pointed out that variations can be high within a species and this is probably due to large variations within individual trees of species having large differences between juvenile and mature wood (Wiemann and Williamson, 1988).

Past and future uses of the collection

The main uses of the CIRAD collection have been i) to compile or contribute to compiling anatomy reference books (Normand, 1972; Normand and Paquis, 1976; Détienne *et al.*, 1982, Détienne and Jacquet 1983) and ii) help in identifying wood specimens for many purposes, such as trade (legal or illegal), justice, culture, history and archaeology (Wheeler, 1998; Gasson, 2011).

This will always be an important role and the existence of well preserved and identified specimens enables the testing of new tools for wood description, such as image analysis, 3D micro-tomography, or chemical spectroscopy.

Another very important field for the basic collection is the ability to measure useful properties by non-destructive methods, such as adsorption spectra using different light sources (X ray, UV or IR, for example), or methods using vibration or ultrasound stress.

Moreover, duplicate specimens for many species make it possible to build databases for many properties, such as shrinkage, strength, rot or insect resistance, as well as isolation and a description of the cocktail of extractives typical of each species, needing destructive tests adapted to small specimens.

Also, Xylaria or wood collections form part of our scientific and wood cultural heritage which can play a role in education and contribute to exhibitions and other museum activities.

[5] Measurement of specific gravity was done directly on the samples in the collection office by simply measuring with a calliper the dimensions in the 3 directions and the mass on a laboratory balance. The uncertainty of measurement can be assumed as i) the sum of balance uncertainty (0.1%), and caliper uncertainties (1.5%) and ii) variations in sample moisture content (maximum 5%) inducing a complementary uncertainty of around 1,5%. The total uncertainty (3%) is always largely below the coefficient of variation within the species or even within the tree.

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